RELATIONS OF TEMPERATURE TO VERTEBRÆ AMONG FISHES.

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It has been known for many years that in certain groups of fishes the northern or cold-water representatives have a larger number of vertebræ than those members which are found in tropical regions. To this generalization, first formulated by Dr. Gill in 1863, we may add certain others which have been more or less fully appreciated by ichthyologists, but which for the most part have never received formal statement. In groups containing fresh water and marine members, the fresh-water forms have in general more vertebræ than those found in the sea. The fishes inhabiting the depths of the sea have more vertebræ than their relatives living near the shore. In free-swimming pelagic fishes the number of vertebræ is also greater than in the related shore fishes of the same regions. The fishes of the earlier geological periods have for the most part numerous vertebræ, and those fishes with the low numbers (24 to 26) found in the specialized spiny-rayed fishes appear only in comparatively recent times. In the same connection we may also bear in mind the fact that those types of fishes (soft-rayed and anacanthine) which are properly characterized by increased numbers of vertebræ predominate in the fresh waters, the deep seas, and in Arctic and Antarctic regions. On the other hand the spiny-rayed* fishes are in the tropics largely in the majority.

* For the purpose of the present discussion, we may regard the ordinary fishes, exclusive of sharks, ganoids, eels, and other primitive or aberrant types as forming three categories: (1) The soft-rayed or Physostomous fishes, with no true spines in the fins, with an open duct to the air-bladder, the ventral fins abdominal (the pelvis being attached only by the flesh and remote from the shoulder-girdle), cycloid scales, etc. (2) The spiny-rayed or Acanthopterygian fishes, having usually spines in the dorsal and other fins, no duct to the air-bladder, the skeleton firm, the ventrals attached by the pelvis to the shoulder-girdle, the shoulder-girdle joined to the skull, and the scales usually ctenoid or otherwise peculiar. The vertebræ among spiny-rayed fishes are larger, and therefore generally fewer in number, and their appendages (shoulder-girdle, gill arches, ribs, interspinal bones, etc.) are more specialized. The spiny-rayed fishes are usually regarded as the most specialized or "highest" in the scale of development. The question of whether, on the whole, they are "higher" or "lower" as compared with sharks and other primitive types is ambiguous, because various ideas are associated with these words "high" or

In the present paper, I wish to consider the extent to which these statements are true and to suggest a line of explanation which cover all these generalizations alike.

STATEMENT OF THEORY.

For the purpose of this discussion we may assume the derivation of species by means of the various influences and processes, for which, without special analysis, we may use the term "natural selection."

By the influence of natural selection, the spiny-rayed fish, so characteristic of the present geological era, has diverged from its soft-rayed ancestry.

The influences which have produced the spiny-rayed fish have been most active in the tropical seas. It is there that "natural selection" is most potent, so far as fishes are concerned. The influence of cold, darkness, monotony, and restriction is to limit the direct struggle for existence, and therefore to limit the resultant changes. In general the external conditions most favorable to fish life are to be found in the tropical seas, among rocks and along the coral reefs near the shore. Here is the center of competition. From conditions otherwise favorable to be found in Arctic regions, the majority of competitors are excluded by their inability to bear the cold. In the tropics is found the greatest variety in surroundings, and therefore the greatest variety in the possible adjustments of series of individuals to correspond with these surroundings.

The struggle for existence in the tropics is a struggle between fish and fish, and among the individuals of a very great number of species, each one acquiring its own peculiar points of advantage. No form is excluded from competition. No competitor is handicapped by loss of strength on account of cold, darkness, foul water, or any condition adverse to fish life.

The influences which serve as a whole to make a fish more intensely and compactly a fish, and which tend to rid it of every character and every organ not needed in fish life, should be most effective along the rocks and shores of the tropics.

For this process of intensification of fish-like characters, which finds its culmination in certain specialized spiny rayed* fishes of the coral reefs, we may conveniently use the term "Ichthyization."

"low." It is certain, however, that the spiny-rayed fishes deviate farthest from the primitive stock, and that the qualities that distinguish fishes as a group are most intensified. In other words, it is in the spiny-rayed fishes that the process of "ichthyization" or fish-forming has gone farthest. A third category would comprise the Anacanthines (cods, flounders, etc.), fishes anatomically similar to the spiny-rayed forms, but without spines to their fins, with weaker skeletons and smaller and more numerous vertebræ. They are "degenerate" or more "generalized" offshoots from the spiny-rayed types, as the eels are from some soft-rayed type.

*The Parrot-fishes (*Scaridæ*), Trigger-fishes (*Balistidæ*), Angel-fishes (*Chætodontidæ*), etc.

If "ichthyization" is in some degree a result of conditions found in the tropics, we may expect to find a less degree of specialization in the restricted and often unfavorable conditions which prevail in the fresh waters, in the cold and exclusion of the Polar Seas, and especially in the monotony, darkness, and cold of the oceanic abysses where light can not penetrate and where the temperature scarcely rises above the freezing point.

An important factor in "ichthyization" is the reduction of the number of segments or vertebræ, and a proportionate increase in the size and complexity of the individual segment and its appendages.

If the causes producing this change are still in operation, we should naturally expect that in cold water, deep water, dark water, fresh waters, and in the waters of a past geological epoch the process would be less complete and the numbers of vertebræ would be larger.

And this, in a general way, is precisely what we find in the examination of skeletons of a large series of fishes.

If this view is correct, we have a possible theory of the reduction in numbers of vertebræ as we approach the equator. It should, moreover, not surprise us to encounter various modifications and exceptions, for we know little of the habits and scarcely anything of the past history of great numbers of species. The present characters of species may depend on occurrences in the past concerning which even guesses are impossible.

HISTORICAL SKETCH.

Günther, 1862.—The earliest observation on record in reference to the subject in question was made by Dr. Albert Günther. He noted that among the *Labridæ*, the species of temperate waters had more vertebræ than those of the tropics. He says:*

> In those genera of *Labridæ* which are composed entirely or for the greater part of tropical species the vertebral column is composed of twenty-four vertebræ, whilst those which are chiefly confined to the temperate seas of the northern and southern hemispheres have that number increased in the abdominal and caudal portions.

Gill, 1863.—Shortly after, in a review of Dr. Günther's work on the Labroids,† Dr. Theodore Gill showed that this generalization was not confined to the Labroids alone, but that "it may also be extended to other families. * * * This generalization is applicable to the representatives of Acanthopterygian‡ families generally, and can be considered in connection with the predominance of true Malacopterygian§ fishes in northern waters, fishes in which the increase in the number of vertebræ is a normal feature."

Gill, 1864.—Later,‖ Dr. Gill remarked that the increase in the num-

* Catalogue of the Fishes of the British Museum, vol. IV, p. 65.

† On the Labroids of the Western Coast of North America, Proc. Ac. Nat. Sc., Phila., 863, p. 221.

‡ Spiny-rayed.

§ Soft-rayed; here including the Anacanthine fishes.

‖ Proceedings Academy Natural Science, Phila., 1864, 147.

ber of vertebræ of *Sebastes*, a genus peculiar to the northern seas, affords an excellent example of the truth of the generalization claiming an increased number of vertebræ for the cold-water representatives of Acanthopterygians.

Jordan, 1886.—In 1886, in a paper before the Indiana Academy of Sciences,* the present writer showed that in very many families the number of vertebræ decreases as we approach the tropics. So constant is this relation that it was thought that it might almost be termed a law. The writer could however suggest no adequate cause by the operation of which such changes are brought about.

Jordan and Goss, 1889.—In a study of the flounders, in 1889,† a table was given showing the numbers of vertebræ in the different species. From this table it was made evident that in that group of flounders,‡ which includes the halibut and its relatives, the Arctic genera§ have from 49 to 50 vertebræ. The northern genera‖ have from 43 to 45, the members of a large semitropical genus¶ of wide range have 35 to 41, while the tropical forms** have from 35 to 37.

In the group of turbots†† and whiffs none of the species really belong to the northern fauna, and the range in numbers is from 35 to 43. The highest number, 43,‡‡ is found in a deep water species, and the next, 41 and 40,§§ in species which extend their range well toward the north.

Among the plaices, which are all‖‖ northern, the numbers range from 35 to 65, the higher numbers, 52, 58, 65, being found in species¶¶ which inhabit considerable depths in the Arctic Seas. The lowest numbers*** (35) belong to shore species which range well to the south.

Concerning this matter, Jordan and Goss remark:

> It has already been noticed by Dr. Günther and others that in certain groups of fishes northern representatives have the number of their vertebræ increased. In no group is this more striking than in the flounders.

Gill, 1889.—In a review††† of the paper above mentioned, Dr. Gill considers in detail the condition of our knowledge of this subject, quoting from the various papers mentioned above, and claiming very properly that the first statement of this generalization belonged to himself rather than to Dr. Günther.

Dr. Gill further adds:

> The case of the Sebastines became still more striking when Messrs. Jordan and Gilbert discovered that the number of vertebræ in the species of *Sebastichthys* and *Sebas-*

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* Still unpublished.

† A Review of the Flounders and Soles (*Pleuronectidæ*) of America and Europe, by David S. Jordan and David K. Goss.

‡ *Hippoglossinæ*. § *Hippoglossus* and *Atheresthes*.

‖ *Hippoglossoides, Lyopsetta*, and *Eopsetta*. ¶ *Paralichthys*.

** *Xystreurys, Ancylopsetta*, etc. †† *Psettinæ*.

‡‡ *Monolene sessilicauda*. §§ *Lepidorhombus whiff-jagonis* and *Citharichthys sordidus*.

‖‖ *Pleuronectinæ*. ¶¶ *Glyptocephalus* and *Microstomus*.

*** *Platichthys stellatus, Hypsopsetta guttulata*.

††† Proceedings of the U. S. National Museum, 1888, p. 604.

todes, genera intermediate between the northern *Sebastes* and the tropical and subtropical representatives of the family of *Scorpænidæ*, was also intermediate.

But while claiming the generalization that there is a correlation between the increase of vertebræ and the increase of latitude among fishes, I would not assign it an undue value or claim for it the dignity of a law. It is simply the expression of a fact which has no cause for its being now known. It may be added that this generalization is true only in a general sense.

Jordan, 1891.—In another paper* the present writer has said:

This increase in the number of vertebræ in northern forms has been used as a basis of classification of the *Pleuronectidæ* by Jordan and Goss, of the *Scorpænidæ* by Jordan and Gilbert, and it will doubtless prove to have a high value in the subdivision of other families which have representatives in different zones. The cause of this peculiarity of fishes of cold waters is still obscure. Probably the reduction in number of segments is a result of the specialization of structure incident to the sharper competition of the tropical waters, where the outside conditions of life are very favorable for fishes, but the struggle of species against species is most severe.

In this paper is given a table which shows that in the genera of *Labridæ*† inhabiting northern Europe and the New England waters there are 38 to 41 vertebræ, in the Mediterranean forms‡ 30 to 33, in certain subtropical genera§ 27 to 29, while in those *Labroids* which chiefly abound about the coral reefs‖ the number is from 23 to 25.

Jordan & Eigenmann, 1891.¶—In a recent paper on the *Serranidæ* (sea-bass and groupers) it is stated that the group as a whole belongs to the tropical seas, and that it differs from the related fresh-water family of *Percidæ* by the much smaller number of vertebræ, usually 24, which is the number most common among spiny rayed fishes. Among the *Serranidæ*, however, two genera form exceptions to the general rule. One of these,** with 35 vertebræ, occurs in the rivers of China, the other,†† with 36 vertebræ, in the mountain streams of Chili and Patagonia. In these two genera the numbers are materially increased, as would be expected if the rule is to hold good. There are, however, other *Serranidæ*, more or less perfectly confined to the fresh waters, and yet retaining the normal number of vertebræ. These are perhaps comparatively recent immigrants from the sea. In evidence of this is the fact that among these forms there is a perfect gradation in habits from the strictly marine,‡‡ through migratory§§ and brackish-water species‖‖ to those confined to the rivers and lakes.¶¶

So far as I know, the above record includes all the references to this subject yet made in ichthyological literature. We may now examine the facts in detail.

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* Review of the Labroid Fishes of America and Europe, p. 2.

† *Labrus, Acantholabrus, Ctenolabrus, Hiatula.*

‡ Chiefly belonging to *Symphodus.* § *Lachnolaimus, Harpe*, etc.

‖ *Scarus, Sparisoma, Xyrichthys, Julis, Thalassoma*, etc.

¶ A Review of the Genera and Species of *Serranidæ* found in the waters of America and Europe, by David S. Jordan and Carl H. Eigenmann.

** *Latcolabrax.* †† *Percichthys.*

‡‡ *Diccntrarchus punctatus.* §§ *Roccus lineatus.*

‖‖ *Morone americana.* ¶¶ *Roccus chrysops.*

NUMBERS OF VERTEBRÆ.

GANOID FISHES.

It may be taken for granted that the ancestry of the various modern types of bony fishes is to be sought among the Ganoids. All the fossil forms in this group have a notably large number of vertebræ. The few now living are nearly all fresh-water fishes, and among these, so far as known, the numbers range from 65 to 110.*

SOFT-RAYED FISHES.

Among the *Teleostei* or bony fishes, those which first appear in geological history are the *Isospondyli*, the allies of the salmon and herring. These have all numerous vertebræ, small in size, and none of them in any notable degree modified† or specialized. In the northern seas *Isospondyli* still exceed all other fishes in number of individuals. They abound in the depths of the ocean, but there are comparatively few of them in the tropics.

The *Salmonidæ*‡ which inhabit the rivers and lakes of the northern zones have from 60 to 65 vertebræ. The *Scopelidæ*, *Stomiatidæ*, and other deep-sea analogues have from 40 upwards in the few species in which the number has been counted.

The group of *Clupeidæ*§ is probably nearer the primitive stock of *Isospondyli* than the salmon are. This group is essentially northern in its distribution, but a considerable number of its members are found within the tropics. The common herring‖ ranges farther into the Arctic regions than any other. Its vertebræ are 56 in number. In the shad,¶ a northern species which ascends the rivers, the same number has been recorded.

The sprat** and sardine†† ranging farther south, have from 48 to 50, while in certain small herring‡‡ which are strictly confined to tropical shores the number is but 40.

Allied to the herring are the anchovies, mostly tropical. The northernmost species,§§ the common anchovy of Europe, has 46 vertebræ. A tropical species|||| has 41 segments.

There are, however, a few soft-rayed fishes¶¶ confined to the tropical seas in which the numbers of vertebræ are still large, an exception to

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* Sixty-seven in *Polypterus*, 110 in *Calamoichthys*, 95 in *Amia*, etc.

† As is indicated by the name *Isospondyli*, from ἴσος, equal, σπονδυλος, vertebra.

‡ Salmon, trout, grayling, whitefish, etc.

§ Herring, shad, sprat, sardine, and their allies.

‖ *Clupea harengus.*

¶ *Clupea alosa*, the European shad.

** *Clupea sprattus.*

†† *Clupea pilchardus.*

‡‡ *Harengula macrophthalma.*

§§ *Stolephorus enchrasicolus.*

|||| *Stolephorus browni.*

¶¶ Among these are *Albula vulpes*, the bonefish, with 70 vertebræ, *Elops saurus*, the ten-pounder, with 72, the Grande Écaille (*Megalops cyprinoides*) with 57, and *Chanos chanos* with 72.

the general rule for which there is no evident reason unless it be connected with the wide distribution of these almost cosmopolitan fishes.

In a fossil herring-like fish from the Green River shales, I count 40 vertebræ; in a bass like or serranoid fish from the same locality 24, these being the usual numbers in the present tropical members of these groups.

The great family of *Siluridæ* or catfishes seems to be not allied to the *Isospondyli*, but a separate offshoot from another ganoid type. This group is represented in all the fresh waters of temperate and tropical America, as well as in the warmer parts of the Old World. One division of the family, containing numerous species abounds on the sandy shores of the tropical seas. The others are all fresh-water fishes. So far as the vertebræ in the *Siluridæ* have been examined, no conclusions can be drawn. The vertebræ in the marine species range from 35* to 50; in the North American forms from 37 to 45,† and in the South American fresh-water species, where there is almost every imaginable variation in form and structure, the numbers range from 28 to 50 or more.

The *Cyprinidæ*,‡ confined to the fresh waters of the northern hemisphere, and their analogues, the *Characinidæ* of the rivers of South America and Africa, have also numerous vertebræ, 36 to 50 in most cases. I fail to detect in either group any relation in these numbers to surrounding conditions.

In general, we may say of the soft-rayed fishes that very few of them are inhabitants of tropical shores. Of these few, some which are closely related to northern forms have fewer vertebræ than their cold-water analogues. In the northern species, the fresh-water species and the species found in the deep sea, the number of vertebræ is always large, but the same is true of some of the tropical species also.

SPINY-RAYED FISHES.

Among the spiny-rayed fishes, the facts are more striking. Of these, numerous families are chiefly or wholly confined to the tropics, and in the great majority of all the species the number of vertebræ is constantly 24,§ 10 in the body and 14 in the tail (10 + 14).

In some families in which the process of ichthyization has gone on to an extreme degree, as in certain *Plectognath* fishes,‖ there has been a

* *Tachisurus*, *Felichthys*, etc.

† *Ictalurus*, *Ameiurus*, etc.

‡ Carp, minnows, suckers, chubs, buffalo-fishes, gudgeons, etc.

§ This is true of all or nearly all the *Serranidæ*, *Sparidæ*, *Sciænidæ*, *Chætodontidæ*, *Hæmulidæ*, *Gerridæ*, *Gobiidæ*, *Acanthuridæ*, *Mugilidæ*, *Sphyræenidæ*, *Mullidæ*, *Pomacentridæ*, etc.

‖ *Balistes*, the trigger fish, 17; *Monacanthus* and *Alutera*, foolfishes, about 20; the trunkfish, *Ostracion*, 14; the puffers, *Tetraodon* and *Spheroides*, 18; *Canthigaster*, 17; and the headfish, *Mola*, 17. Among the *Pediculates*, *Malthe* and *Antennarius* have 17 to 19 vertebræ, while in their near relatives, the anglers, *Lophiidæ*, the number varies

still further reduction, the lowest number, 14, existing in the short inflexible body of the trunkfish,* in which the vertebral joints are movable only in the base of the tail. In all these forms, the process of reduction of vertebræ has been accompanied by specialization in other respects. The range of distribution of these fishes is chiefly though not quite wholly confined to the tropics.

A very few spiny-rayed families are wholly confined to the northern seas. One of the most notable of these is the family of viviparous surf fishes,† of which numerous species abound on the coasts of California extending to Oregon, and Japan, but which enter neither the waters of the frigid nor the torrid zone. These fishes seem to be remotely connected with the *Labridæ*‡ of the tropics, but no immediate proofs of their origin exist. The surf fishes have from 32 to 42 vertebræ, numbers which are never found among tropical fishes of similar appearance or relationship.

The case of the *Labridæ*, in which the fact was first noticed, has been already mentioned. Equally striking are the facts in the great group of *Cataphracti*, or mailed-cheek fishes, a tribe now divided into several families, diverging from each other in various respects, but agreeing in certain peculiarities of the skeleton.§

Among these fishes the family most nearly related to ordinary fishes is that of the *Scorpænidæ*.‖

This is a large family containing many species, fishes of local habits, swarming about the rocks at moderate depths in all zones. The species of the tropical genera have all 24 vertebræ.¶ Those genera chiefly found in cooler waters, as in California,** Japan, Chili, and the Cape of Good Hope, have in all their species 27 vertebræ, while in the single Arctic genus there are 31.†† An Antarctic genus‡‡ bearing some relation to *Sebastes* has 39.

Allied to the *Scorpænidæ*, but confined to the tropical or semitropical

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with the latitude. Thus, in the northern angler, *Lophius piscatorius*, which is never found south of Cape Hatteras, there are 30 vertebræ, while in a similar species, inhabiting both shores of the tropical Pacific, *Lophiomus setigerus*, the vertebræ are but 19. Yet, in external appearance, these two fishes, are almost identical. It is, however, a notable fact that some of the deep-water *Pediculates*, or angling fishes, have the body very short and the number of vertebræ correspondingly reduced. *Dibranchus atlanticus*, from a depth of 3,600 fathoms, or more than 4 miles, has but 18 vertebræ, and others of its relatives in deep waters show also small numbers. These soft-bodied fishes are simply animated mouths, with a feeble osseous structure, and they are perhaps recent offshoots from some stock which has extended its range from muddy bottom or from floating seaweed to the depths of the sea.

* *Ostracion*.

† *Embiotocidæ*.

‡ Wrasse fishes, old wives, parrot fishes, cunners, tautogs, redfishes, señoritas, etc.

§ Notably by the formation of a bony "stay" to the preopercle by the backward extension of one of the suborbital bones.

‖ Sea scorpions, rockfishes, "rock cod," rosefishes, etc.

¶ *Scorpæna*, *Sebastoplus*, *Pterois*, *Synanceia*, *Synancidium*, etc.

** *Sebastichthys* and its offshoots, *Sebastodes*, *Sebastopsis*, etc, the "rock cod" of California.

†† The rosefish, *Sebastes*.

‡‡ *Agriopus*.

seas, are the *Platycephalidæ*, with 27 vertebræ, and the *Cephalacanthidæ*, with but 22. In the deeper waters of the tropics are the *Peristediidæ*, with 33 vertebræ, and extending farther north, belonging as much to the temperate as to the torrid zone, is the large family of the *Triglidæ*,* in which the vertebræ range from 25 to 38.

The family of *Agonidæ*,† with 36 to 40 vertebræ, is still more decidedly northern in its distribution. Wholly confined to northern waters is the great family of the *Cottidæ*,‡ in which the vertebræ ascend from 30 to 50. Entirely polar and often in deep waters are the *Liparididæ*,§ an offshoot from the *Cottidæ*, with soft, limp bodies, and the vertebræ 35 to 65. In these northern forms there are no scales, the spines in the fins have practically disappeared, and only the anatomy shows that they belong to the group of spiny-rayed fishes. In the *Cyclopteridæ*,‖ likewise largely arctic, the body becomes short and thick, the backbone inflexible, and the vertebræ are again reduced to 28. In most cases, as the number of vertebræ increases, the body becomes proportionally elongate. As a result of this, the fishes of arctic waters are, for the most part, long and slender, and not a few of them approach the form of eels. In the tropics, however, while elongate fishes are common enough, most of them (always excepting the eels) have the normal number of vertebræ, the greater length being due to the elongation¶ of their individual vertebræ and not to their increase in number.

In the great group of blenny-like fishes the facts are equally striking. The Arctic species are very slender in form as compared with the tropical blennies, and this fact, caused by a great increase in the number of their vertebræ, has led to the separation of the group into several families. The tropical forms composing the family of *Blenniidæ*** have from 28 to 49 vertebræ, while in the Arctic genera the numbers range from 75 to 100.

The Anacanthine fishes in whole or in part seem to have sprung from a Blennioid stock. Of these the most specialized group is that of the flounders,†† already described. The wide distribution of this family, its

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* The gurnards and sea robins. The lowest numbers are found in the American genus *Prionotus*, which is chiefly tropical, the highest in *Lepidotrigla*, which is confined to southern Europe.

† Sea poachers, alligator fishes, etc.

‡ Sculpins, Miller's thumbs, etc.

§ Sea snails.

‖ Lumpfishes.

¶ Thus the very slender goby, *Gobius oceanicus*, has the same number (25) of vertebræ as its thick-set relative *Gobius soporator* or the chubby *Lophogobius cyprinoides*.

** Of the true *Blenniidæ*, which are all tropical or semi-tropical, *Blennius* has 28 to 35 vertebræ; *Salarias*, 35 to 38; *Labrosomus*, 34; *Clinus*, 49; *Cristiceps*, 40. A fresh-water species of *Cristiceps* found in Australia has 46. Blennioid fishes in the Arctic seas are *Anarrhichas*, with 76 vertebræ; *Anarrhichthys*, with 100 or more; *Lumpenus*, 79; *Muraenoides*, 85; *Lycodes*, 112; *Gymnelis*, 93. *Lycodes* and *Gymnelis* have lost all the dorsal spines and are intermediate between the blennies and the forms called *Anacanthine*. The gradual degeneration of such northern forms may perhaps be attributed to the influence of "Panmixia" or the cessation of selection.

†† *Pleuronectidæ*,

members being found on the sandy shores of all zones, renders it especially important in the present discussion. The other Anacanthine families are chiefly confined to the cold waters or to the depths of the seas.

In the Cod family* (*Gadidæ*) the number of vertebræ is usually about 50, and in their deep-sea allies, the grenadiers† or rat-tails, the numbers range from 65 to 80.

FRESH-WATER FISHES.

Of the families confined strictly to the fresh waters the great majority are among the soft-rayed or physostomous fishes, the allies of the salmon,‡ pike, carp, and cat-fish. In all of these the vertebræ are numerous. A few fresh-water families have their affinities entirely with the more specialized forms of the tropical seas. Of these the *Centrarchidæ* (comprising the American fresh-water sun-fish§ and black bass‖) have on the average about 30 vertebræ, the pirate perch¶ 29, and the perch** family, perch and darters, etc., 35 to 45, while the *Serranidæ* or sea bass, the nearest marine relatives of all these, have constantly 24. The marine family of Demoiselles†† have 26 vertebræ, while 30 to 40 vertebræ usually exist in their fresh-water analogues (or possibly descendants), the *Cichlidæ*, of the rivers of South America and Africa. The sticklebacks,‡‡ a family of spiny fishes, confined to the rivers and seas of the north, have from 31 vertebræ to 41.

PELAGIC FISHES.

It is apparently true that among the free swimming, or migratory pelagic fishes, the number of vertebræ is greater than among their relatives of local habits. This fact is most evident among the Scombriform fishes, the allies of the mackerel and tunny. All of these belong properly to the warm seas, and the reduction of the vertebræ in certain forms has no evident relation to the temperature, though it seems to be related in some degree to the habits of the species. Perhaps the retention of many segments is connected with that strength and swiftness in the water for which the mackerels are preëminent.

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* Fifty-one in the codfish (*Gadus callarias*), 58 in the Siberian cod (*Pleurogadus navaga*), 54 in the haddock (*Melanogrammus aglifinus*), 54 in the whiting (*Merlangus merlangus*), 54 in the coal-fish (*Pollachius virens*), 52 in the Alaskan coal-fish (*Pollachius chalcogrammus*), 51 in the hake (*Merluccius merluccius*). In the burbot (*Lota lota*), the only fresh-water codfish, 59; in the deep-water ling (*Molva molva*), 64; in the rocklings (*Gaidropsarus*), 47 to 49. Those few species found in the Mediterranean and the Gulf of Mexico have fewer fin rays and probably fewer vertebræ than the others, but none of the family enter warm water, the southern species living at greater depths.

† *Macruridæ*.

‡ *Cyprinidæ*, *Salmonidæ*, *Esocidæ*, *Characinidæ*, *Cyprinodontidæ*, *Siluridæ*, etc.

§ *Lepomis*.

‖ *Micropterus*.

¶ *Aphredoderidæ*.

** *Percidæ*.

†† *Pomacentridæ*.

‡‡ *Gasterosteidæ*.

The variations in the number of vertebræ in this group led Dr. Günther, nearly 30 years ago, to divide it into two families, the *Carangidæ* and *Scombridæ*.

The *Carangidæ** are tropical shore fishes, local or migratory to a slight degree. All these have from 24 to 26 vertebræ. In their pelagic relatives, the dolphins,† there are from 30 to 33; in the opahs,‡ 45; in the Brama, 42; while the great mackerel family,§ all of whose members are more or less pelagic, have from 31 to 50.

Other mackerel-like fishes are the cutlass‖ fishes, which approach the eels in form and in the reduction of the fins. In these the vertebræ are correspondingly numerous, the numbers ranging from 100 to 160.

In apparent contradistinction to this rule, however, the pelagic family of swordfishes,¶ remotely allied to the mackerels, and with even greater powers of swimming, has the vertebræ in normal number, the common swordfish having but 24.

THE EELS.

The eels constitute a peculiar group of uncertain, but probably soft-rayed, ancestry, in which everything else has been subordinated to muscularity and flexibility of body. The fins, girdles, gill arches, scales, and membrane bones are all imperfectly developed or wanting. The eel is perhaps as far from the primitive stock as the most highly "ichthyized" fishes, but its progress has been of another character. The eel would be regarded in the ordinary sense as a degenerate type, for its bony structure is greatly simplified as compared with its ancestral forms, but in its eel-like qualities it is, however, greatly specialized. All the eels have vertebræ in great numbers. As the great majority of the species are tropical, and as the vertebræ in very few of the deep-sea forms have been counted, no conclusions can be drawn as to the relation of their vertebræ to the temperature.

It is evident that the two families most decidedly tropical in their distribution, the morays** and the snake eels,†† have diverged farthest from the primitive stock. They are most "degenerate," as shown by the reduction of their skeleton. At the same time they are also most decidedly "eel-like," and in some respects, as in coloration, dentition,

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* Pampanos, amber fishes, pilot fishes, cavallas, etc.

† *Coryphæna*. ‡ *Lampris*.

§ *Scombridæ*. The mackerel (*Scomber scombrus*) has 31 vertebræ: the chub mackerel (*Scomber colias*), 31; the tunny (*Albacora thynnus*), 39; the long-finned albacore (*Albacora alalonga*), 40; the bonito (*Sarda sarda*), 50; the Spanish mackerel (*Scomberomorus maculatus*), 45.

‖ *Trichiuridæ*: *Aphanopus*, 101 vertebræ; *Lepidopus*, 112; *Trichiurus*, 159.

¶ *Xiphiida*.

** *Muræniдæ*. Among the morays, *Muræna helena* has 140; *Gymnothorax meleagris*, 120; *G. undulatus*, 130; *G. moringa*, 145; *G. concolor*, 136; *Echidna catenata*, 116; *E. nebulosa*, 142; *E. zebra*, 135. In other families the true eel, *Anguilla anguilla*, has 115; the Conger eel, *Conger conger*, 156; and *Muræsox cinereus*, 154.

†† *Ophisuridæ*.

muscular development, most highly specialized. It is evident that the presence of numerous vertebral joints is essential to the suppleness of body which is the eel's chief source of power.

So far as known the numbers of vertebræ in eels range from 115 to 160, some of the deep-sea eels* having probably higher numbers, if we can draw inferences from their slender or whip-like forms; but this character may be elusive.

THE SHARKS.

The sharks show likewise a very large number of vertebræ, 130 to 150 in the species in which they have been counted. In these fishes no comparative study of the vertebræ has been made. The group is a very ancient one in geological time, and in the comparatively few remaining members of the group, the vertebræ, in fact the entire skeleton, is in a very primitive condition. The sharks are free-swimming fishes, and with them as with the eels, flexibility of body is essential to the life they lead.

VARIATIONS IN FIN-RAYS.

In some families the number of rays in the dorsal and anal fins is dependent on the number of vertebræ. It is therefore subject to the same fluctuations.† This relation is not strictly proportionate, for often a variable number of rays with their interspinal processes will be interposed between a pair of vertebræ. The myotomes or muscular bands on the sides are usually coincident with the number of vertebræ. As, however, these and other characters are dependent on differences in vertebral segmentation, they bear the same relations to temperature that the vertebræ themselves sustain.

CONCLUSION.

From the foregoing examples we may conclude that, other things being equal, the numbers of vertebræ are lowest in the shore-fishes of the tropics, and especially in those of local habits, living about rocks and coral reefs.

The cause of this is to be found in the fact that in these localities the influences of natural selection are most active. The reduction of vertebræ may be regarded as a phase in the process of specialization which has brought about the typical spiny-rayed fish.

These influences are most active in the warm, clear waters of tropical shores, because these regions offer conditions most favorable to fish-life, and to the life of the greatest variety of fishes. No fish is ex-

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* *Nemichthys*, *Nettastoma*.

† Thus in the *Scorpænidæ*, *Sebastes*, the Arctic genus has the dorsal rays XV, 13, the vertebræ 12 + 19. The tropical genus *Scorpæna* has the dorsal rays XII, 10, the vertebræ 10 + 14, while the semitropical genus *Sebastichthys* has the intermediate numbers of dorsal rays XII, 12, and vertebræ 12 + 15.

cluded from competition. There is the greatest variety of competitors, the greatest variety of fish-food, and the greatest variety of conditions to which adaptation is possible. The number of species visiting any single area is vastly greater in the tropics than in cold regions.

A single drawing of the net on the shores of Cuba* will obtain more different kinds of fish than can be found on the coasts of Maine in a year. Cold, monotony, darkness, isolation, foul water; all these are characters opposed to the formation of variety in fish-life. The absence of these is a chief feature of life in the tropical waters.

The life of the tropics, so far as the fishes are concerned, offers analogies to the life of cities, viewed from the standpoint of human development. In the same way, the other regions under consideration are, if we may so speak, a sort of ichthyological backwoods. In the cities, in general, the conditions of individual existence are most easy, but the competition is most severe. The struggle for existence is not a struggle with the forces and conditions of nature. It is not a struggle with wild beasts, unbroken forests, or a stubborn soil, but a competition between man and man for the opportunity of living.

It is in the cities where the influences which tend to the modernization and concentration of the characters of the species, the intensification of human powers and their adaptation to the various special conditions go on most rapidly. That this intensification is not necessarily progress either physically or morally is aside from our present purpose.

It is in the cities where those characters and qualities not directly useful in the struggle for existence are first lost or atrophied.

Conversely it is in the "backwoods," the region most distinct from human conflicts, where primitive customs, antiquated peculiarities, and useless traits are longest and most persistently retained. The life of the backwoods will be not less active and vigorous, but it will lack specialization.

It is not well to push this analogy too far, but we may perhaps find in it a suggestion as to the development of the eels. In every city there is a class which partakes in no degree of the general line of development. Its members are specialized in a wholly different way, thereby taking to themselves a field which the others have abandoned, and making up in low cunning what they lack in strength and intelligence.

Thus among the fishes we have in the regions of closest competition a degenerate and non-ichthyized form, lurking in holes among rocks and creeping in the sand, thieves and scavengers among fishes.

The eels fill a place which would otherwise be left unfilled. In their way, they are perfectly adapted to the lives they lead. A multiplicity of vertebral joints is useless to the typical fish, but to the eel strength and suppleness are everything, and no armature of fin or scale or bone so desirable as its power of escaping through the smallest opening.

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*In 1884 a single haul of a net in a shallow bay on Key West brought in seventy-five species. A week's work about Martha's Vineyard yielded but forty-eight kinds.

It may be too that, as rovers in the open sea, the strong swift members of the mackerel family find a positive advantage in the possession of many vertebræ, and that to some adaptation to their mode of life we must attribute their lack of "ichthyization" of the skeleton. But this is wholly hypothetical, and we may leave the subject with the general conclusion that with the typical fish advance in structure has specialized the vertebræ, increased their size and the complexity of their appendages, while decreasing their number. That with some exceptions and modifications this reduction is characteristic of fishes in the tropics, and that it is so because in the tropics the processes of evolution are most active, so far as the fishes are concerned.